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- (71) Applicant (for US only): **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).
- (71) Applicant (for CA only): **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125 - 9 Avenue SE, Calgary, Alberta T2G 0P6 (CA).
- (71) Applicant (for FR only): **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, 75007 Paris (FR).
- (71) Applicant (for all designated States except CA, FR, US): **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89m, NL-2514 JG The Hague (NL).
- (72) Inventors: **CAMACHO CARDENAS, Alejandro**; 7 Ben-oi Crescent, Singapore 629971 (SG). **ESLINGER, David Milton**; 15718 N 102nd E Avenue, Collinsville, Oklahoma 74021 (US).
- (74) Agents: **STONEBROOK, Michael** et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).

[Continued on next page]

(54) Title: SUBMERSIBLE PUMPING SYSTEM WITH DYNAMIC FLOW BYPASS

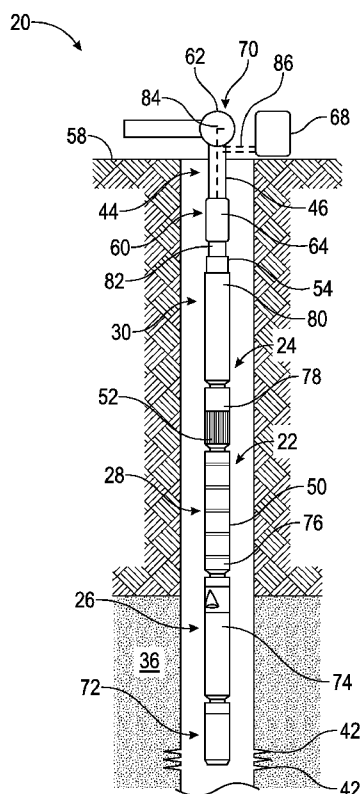


FIG. 3

(57) Abstract: A technique facilitates operation of an electric submersible pumping system. The electric submersible pumping system may be operated to create a fluid flow by pumping fluid along a primary flow path. The fluid flow is monitored to detect a decrease in fluid flow rate which can be detrimental to the electric submersible pumping system. Upon detecting the decrease in fluid flow rate, at least a portion of the fluid flow is diverted away from the primary flow path to help normalize operation of the electric submersible pumping system.



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PATENT APPLICATION

SUBMERSIBLE PUMPING SYSTEM WITH DYNAMIC FLOW BYPASS**CROSS-REFERENCE TO RELATED APPLICATION**

[0001] The present document is based on and claims priority to U.S. Provisional Application Serial No.: 62/142,664, filed April 3, 2015, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] In many hydrocarbon well applications, electric submersible pumping (ESP) systems are used for pumping of fluids, e.g. hydrocarbon-based fluids. For example, the ESP system may be conveyed downhole and used to pump oil from a downhole wellbore location to a surface collection location along a fluid flow path. During operation of the ESP system, flow restrictions sometimes occur along the fluid flow path and those flow restrictions can force the ESP system to operate at a low-flow or no-flow condition. Such restrictive flow conditions may be planned, unplanned, or accidental, e.g. unnoticed. However, the restrictive flow conditions can cause the ESP

system to experience increased stress, e.g. increased pressure loads and temperatures, which can lead to accelerated wear and premature failure.

SUMMARY

[0003] In general, a system and methodology facilitate operation of an electric submersible pumping system. When operated, the electric submersible pumping system pumps a fluid and creates a fluid flow along a primary flow path. The fluid flow is monitored to detect a decrease in fluid flow rate which can be detrimental to the electric submersible pumping system. Upon detecting the decrease in fluid flow rate, at least a portion of the fluid flow is diverted away from the primary flow path to help normalize operation of the electric submersible pumping system.

[0004] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0006] Figure 1 is a schematic illustration of a well system comprising an example of an electric submersible pumping system positioned in a borehole, e.g. a wellbore, according to an embodiment of the disclosure;

[0007] Figure 2 is a schematic illustration of a well system comprising another example of an electric submersible pumping system positioned in a borehole, e.g. a wellbore, according to an embodiment of the disclosure;

[0008] Figure 3 is a schematic illustration of a well system comprising another example of an electric submersible pumping system positioned in a borehole, e.g. a wellbore, according to an embodiment of the disclosure; and

[0009] Figure 4 is a schematic illustration of an example of a control system which may be used to obtain sensor data regarding operation of the electric submersible pumping system and/or perform control operations with respect to the electric submersible pumping system, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0010] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0011] The present disclosure generally relates to a system and methodology which facilitate operation of an electric submersible pumping system. During normal operation of the electric submersible pumping system, fluid is pumped to create a fluid flow along a primary flow path. In well applications, the pumped fluid may be a production fluid, e.g. petroleum, or other well fluid directed along the primary flow path to a desired location, e.g. a surface collection location. The fluid flow is monitored to detect a decrease in fluid flow rate which could be detrimental to the electric submersible pumping system. The decrease in fluid flow rate may be a predetermined reduction in fluid flow along the primary flow path. The decrease in fluid flow rate also can be due to many sources including, but not limited to: surface blockage, downhole blockage (either

upstream or downstream of the electric submersible pumping system), change in well productivity, change in fluid composition (e.g. change in gas ratio or other constituent ratio change), change in fluid properties, and/or other sources. Upon detecting the decrease in fluid flow rate, at least a portion of the fluid flow is diverted away from the primary flow path to help normalize operation of the electric submersible pumping system.

[0012] Depending on the application, the fluid flow may be diverted by a controllable valve which is selectively actuated to divert the entire fluid flow or at least a desired portion of the fluid flow. In some embodiments, the valve serves as a dynamic recirculation valve which may be selectively actuated to direct at least some of the fluid flow back to an intake of the electric submersible pumping system. In other embodiments, at least some of the fluid flow is directed to a different location away from the intake of the electric submersible pumping system, e.g. to a location below the motor of the electric submersible pumping system to aid cooling of the motor. Other types of flow diverter devices also may be employed for a given operation.

[0013] The system and methodology described herein may be used to prevent an electric submersible pumping system from operating at no-flow or low-flow conditions when a flow restriction occurs along the primary flow path. The system utilizes the diverter device, e.g. diverter valve system, which can be dynamically opened and closed to divert at least a portion of the fluid flow away from the primary flow path and to thus keep the electric submersible pumping system operating with desired flow rates during the downstream flow restriction event. Opening and closing of the diverter device may be done on command or automatically by, for example, a processor-based controller.

[0014] In some applications, the diverter device may be positioned to enable selective creation of an opening proximate a discharge of the electric submersible pumping system. The opening proximate the discharge may be connected back to an intake of the pumping system to provide a controlled partial or total recirculation of the pumped fluid. A sensor system may be used to monitor the fluid flow to determine a

reduction in fluid flow indicative of the flow restriction. In automated embodiments, the sensor system may be coupled with the processor-based controller or other type of control system. The diverter device may be positioned at various distances from the electric submersible pumping system depending on a desired recirculation volume, pattern or timing, and/or other factors. In some embodiments, multiple diverter devices may be employed and operated simultaneously or independently with respect to each other. The multiple diverter devices may be used to set a desired recirculation regime or to act as a redundant system for backup purposes.

[0015] Referring generally to Figure 1, an example of a well system 20 is illustrated as deployed in a borehole 22, e.g. a wellbore. In this embodiment, the well system 20 may comprise an electric submersible pumping system 24 having a variety of components depending on the particular application and/or environment in which it is operated. The illustrated electric submersible pumping system 24 comprises a submersible electric motor 26, a motor protector 28, and a submersible pump 30 powered by the submersible electric motor 26. In some embodiments, the submersible pump 30 may be in the form of a centrifugal pump having two or more stages 32, e.g. compression stages, with each stage having an impeller and a diffuser. By way of example, the pump stages 32 may be characterized according to the angle of flow passages in the impellers, e.g. radial flow stages, mixed flow stages, or axial flow stages. A thrust bearing 34 may be used to resist the net thrust load, e.g. down thrust load, resulting from rotation of the impellers.

[0016] As illustrated, the borehole 22 may be a wellbore drilled into a geologic formation 36 containing a desirable production fluid 38, e.g. petroleum. However, the electric submersible pumping system 24 may be used with a variety of other types of boreholes and other types of fluids. In some applications, the wellbore 22 may be lined with a casing 40 and perforations 42 may be formed through the casing 42 enable flow of fluid, e.g. production fluid, between the surrounding formation 36 and the wellbore 22.

[0017] The electric submersible pumping system may be deployed in borehole 22 via a conveyance system 44 which may have a variety of configurations. For example, conveyance system 44 may comprise tubing 46, e.g. coiled tubing or production tubing, or another suitable conveyance, such as cable. The conveyance system 44 is coupled with electric submersible pumping system 24 by a connector 48. Power may be provided to the submersible motor 26 via a power cable 50.

[0018] Electric power is provided to submersible motor 26 via power cable 50 so as to operate the submersible motor 26. The submersible motor 26, in turn, powers the operation of submersible pump 30 which is then able to draw in fluid 38 through a pump intake 52 and to discharge the pumped fluid through a discharge 54. The fluid flow pumped through discharge 54 flows along a primary flow path 56 to a desired location, e.g. a desired collection location at a surface 58 of the earth. In the example illustrated, the primary flow path 56 is along an interior of tubing 46 but the primary flow path 56 can be disposed along an annulus surrounding conveyance 44 or along another suitable passage.

[0019] At least a portion of the fluid flow passes a diverter device 60 which is in fluid communication with discharge 54. The diverter device 60 may be selectively actuated to divert at least a portion of the fluid flow from the primary flow path 56, as described in greater detail below. By way of example, the diverter device 60 may be positioned along tubing 46 and the fluid flow from discharge 54 may be directed through the diverter device 60.

[0020] In some applications, submersible pump 30 is a centrifugal pump having a plurality of impellers which are rotated via a shaft powered by submersible motor 26. Rotation of the impellers causes fluid to be drawn in through the pump intake 52 so that it may be pumped through the stages 32 and directed to primary flow path 56 via discharge 54. With centrifugal pumps and other types of pumps, a restriction, e.g. blockage, of flow along primary flow path 56 causes a decrease in flow rate with respect to the fluid flowing along primary flow path 56. Consequently, the pump head (pressure) generally

increases and the pump efficiency dramatically decreases which can lead to detrimental thrust loads and/or heat. Additionally, the no-flow or low-flow condition also causes a lower amount of fluid flow past submersible motor 26 and thus a reduced cooling effect. This can lead to harmful temperature increments at the submersible motor 26 and/or other components of electric submersible pumping system 24.

[0021] Referring generally to Figure 2, another embodiment of system 20 is illustrated. In this example, system 20 is a well system and electric submersible pumping system 24 is deployed in wellbore 22 for production of petroleum or other desired fluids. In a normally operating production mode, the electric submersible pumping system 24 is operated to pump a production fluid from a downhole location in wellbore 22 to a wellhead 62 via primary flow path 56.

[0022] During a low-flow or no-flow period, however, the diverter device 60 may be shifted to a position which closes off fluid flow (or at least a portion of the flow) to wellhead 62. The diverter device 60 effectively diverts the fluid flow, e.g. the entire fluid flow or at least a portion of the fluid flow, to another location to enable the electric submersible pumping system 24 to continue pumping fluid at a desired flow rate, e.g. a normal flow rate. By way of example, the diverter device 60 may be in the form of a valve 64 or a plurality of valve 64 which may be actuated to block flow along the primary flow path 56 and to divert that portion of the flow to another location. Valve(s) 64 may be in the form of ball valves, sliding sleeves, spool valves, multi-position valves, and/or other suitable valves which may be controllably actuated between different flow positions.

[0023] In the illustrated example, the diverted flow is directed into the wellbore 22 and back to the pump intake 52, as represented by arrows 66, to establish a recirculation system. In some applications, the recirculation flow 66 may be routed through a dedicated tubing back to pump intake 52. In other applications, the recirculation flow may be routed below the submersible motor 26 and/or to other useful locations within the wellbore 22. The fluid flow which is diverted and redirected to

pump intake 52 may then be drawn into the electric submersible pumping system 24 and continually recirculated until the diverter device 60, e.g. valve(s) 64, is shifted to again direct increased flow along primary flow path 56. In this example, shifting of the diverter device 60 back to the original position enables the production fluid to be pumped along primary flow path 56 to wellhead 62 rather than back to the pump intake 52. In some applications, the dynamic recirculation valve 64 (or other diverter device 60) may be shifted to a position such that a portion of the entire production fluid flow is directed along the primary flow path 56 to the wellhead 62 and the other portion of the production flow is directed back to the pump intake 52 or to another desired location. Thus, the diverter device 60 and dynamic recirculation valve 64 may be selectively used in combination with pump intake 52 as a recirculation system.

[0024] Referring again to Figure 2, actuation of the diverter device 60 may be controlled via a control system 68, e.g. a processor-based control system. In some embodiments, the control system 68 comprises a computer control system located at surface 58. It should be noted, however, the control system 68 may be located in whole or in part downhole, at the surface 58, and/or at locations remote from the wellsite. In some applications, information, e.g. data, on the restricted flow along primary flow path 56 may be provided to control system 68 via a sensor system 70. Based on data from sensor system 70, the diverter device 60 may be shifted to divert the entire fluid flow or a portion of the fluid flow to a desired location, e.g. a location proximate pump intake 52. Depending on the application, the actuation of diverter device 60 may be performed by an operator or autonomously by control system 68.

[0025] Referring generally to Figure 3, another embodiment of system 20 is illustrated as comprising electric submersible pumping system 24 deployed in wellbore 22. In this example, sensor system 70 comprises a variety of sensors which may be used to provide data to control system 68. In some applications, the system 20 also may comprise a downhole control system 72 disposed at the bottom end of submersible motor 26 or at another suitable location. The downhole control system 72 may be used alone or

in cooperation with control system 68 to, for example, control operation of submersible motor 26 and/or diverter device 60.

[0026] For example, downhole control 72 may be used to collect sensor data and to provide the data to control system 68 and/or to receive and execute control instructions from control system 68. In some applications, the downhole control system 72 may be used to obtain sensor data from sensor system 70 and to control actuation of diverter device 60 and/or submersible motor 26 based on that sensor data. However, other embodiments may simply utilize control system 68, e.g. a surface control system, for obtaining data from sensor system 70 and for processing that data to determine the appropriate flow position for diverter device 60.

[0027] With respect to sensor system 70, a variety of sensors may be utilized to monitor desired parameters related to fluid flow along primary flow path 56, fluid flow along diverted flow path 66, operation of electric submersible pumping system 24, and/or other parameters. For example, the submersible motor 26 may be equipped with one or more sensors 74, e.g. temperature sensors and/or vibration sensors. The sensor system 70 also may comprise sensors 76 positioned along motor protector 28 and those sensors may comprise vibration sensors, load sensors, and/or other desired sensors.

[0028] Similarly, the sensor system 70 may comprise intake sensors 78, e.g. pressure sensors, temperature sensors, vibration sensors, and/or other desired sensors, located in or on pump intake 52. The submersible pump 30 and/or discharge 54 also may be equipped with one or more sensors 80, e.g. pressure sensors, temperature sensors, vibration sensors, and/or other suitable sensors. In some embodiments, sensor system 70 comprises a flow rate sensor 82 which may be disposed between discharge 54 and diverter device 60 or at another suitable location. Sensor system 70 also may utilize sensors 84 positioned in or at wellhead 62 and those sensors may comprise pressure sensors, temperature sensors, flow rate sensors, and/or other suitable sensors.

[0029] In a variety of applications, the various sensors of sensor system 70 are placed in communication with surface control 68 via suitable hardwired and/or wireless communication lines 86. By way of example, the surface control 68 may be a computer system having a processor-based control able to receive the data from the various sensors of sensor system 70 to determine the presence of a flow restriction or other anomaly indicating the desirability of actuating diverter device 60. For example, control system 68 may be used to determine whether the electric submersible pumping system 24 is operating outside a predetermined operating range. In some embodiments, the surface control system 68 (or otherwise located control system 68) may be programmed to autonomously control the flow position of diverter device 60.

[0030] It should further be noted that some embodiments of sensor system 70 utilize sensors distributed at least in part in and/or on electric submersible pumping system 24 and those sensors are operatively coupled with the surface control system 68 and/or downhole control logic of downhole control system 72. Control systems 68, 72 may be used alone or in combination to determine, for example, whether the electric submersible pumping system is operating outside a predetermined operating range based on signals from the sensor or sensors. In this latter example, the control logic may be programmed to automatically adjust the speed of submersible motor 26 and/or to automatically actuate diverter device 60 and/or valves at wellhead 62. In some applications, the control system 68 and/or downhole control system 72 may be programmed to automatically actuate the dynamic recirculation valve 64/diverter device 60 to maintain operation of the electric submersible pumping system within a desired flow regime.

[0031] In some embodiments, the diverter valve 64 may be actuatable to a plurality of variable positions to adjust the level of fluid flow diverted, e.g. recirculated. In other embodiments, the dynamic diverter valve 64 may be in the form of a valve actuatable between a fully open or fully closed flow position. Regardless, control logic in control system 68 (and/or downhole control system 72) may be programmed to automatically actuate the valve 64 to a desired position to achieve a desired flow

operating point with respect to the electric submersible pumping system 24. A closed loop control may be employed to provide feedback to the control system 68/72, thus enabling adjustment of flow in real time via actuation of the dynamic diverter valve 64 or other diverter device 60.

[0032] The control system 68/72 also may be used to autonomously determine whether to continue operation in the bypass/recirculation mode with a fully open diverter device 60. For example, the control system may be programmed to redirect at least a portion of the fluid flow until the downstream flow restriction along primary flow path 56 has been removed and the normalized operation of electric submersible pumping system 24 can be resumed. This ability to provide a controlled diversion of at least a portion of the fluid flow along primary flow path 56 can greatly prolong the run life of the electric submersible pumping system while protecting the system equipment during harmful transients.

[0033] In some embodiments, however, the diverter device 60 may be actuated on command. For example, manual control may be used for operations where it is desired to keep the electric submersible pumping system 24 operating but without flow to the surface. Manual control also may be used during well maintenance operations. In some applications, the control system may be switched between autonomous control and manual control. An electric submersible pump control system, in communication with a recirculating control system, also may be used to alter operating parameters of the electric submersible pumping system 24. The operating parameters may be altered to modify performance of the electric submersible pumping system 24 while recirculation is taking place (either automatically or on command). Both the primary control system for the electric submersible pumping system 24 and the recirculation control system can work independently, in communication with each other, or as an integrated single control system. In some applications, surface control system 68 may be used to control electric submersible pumping system 24 and downhole control system 72 may be utilized as the recirculation control system. However, the control capabilities of systems 68, 72 may be utilized in a variety of control regimes.

[0034] The diverter device 60 may be located proximate, e.g. slightly downstream of, pump discharge 54 or at positions between tandem submersible pumps 30. In some applications, a plurality of diverter devices 60 can be employed in cooperation with the electric submersible pumping system 24. Additionally, the sensors of sensor system 70 may be of a variety of types and may be located in a variety of arrangements and quantities along the overall system 20. In some applications, various sensors may be used to determine a flow condition of well system 20 in lieu of a dedicated flow meter. Additional sensors also may be used provide redundancy with respect to a flow meter type sensor.

[0035] According to an embodiment, a differential pressure may be created by, for example, an orifice, and this differential pressure may be used to dictate the flow position of the diverter device 60/valve 64. The flow position may be based on logic programmed into surface control system 68 (and/or downhole control system 72). During certain operations, the dynamic valve 64 (or other diverter device 60) may be actuated to completely block flow along primary flow path 56. Such a closed operating configuration can be useful, for example, to enable clearing of operational transients such as gas-lock and gas slugs.

[0036] Referring generally to Figure 4, an example of a computer-based processing system is illustrated. For purposes of explanation, the illustrated computer-based processing system will be referred to as surface control system 68. However, the description may apply to downhole control system 72 and/or other types of control systems which are located, in whole or in part, downhole, at the surface, or at a remote location with respect to the wellsite.

[0037] In the example of Figure 4, control system 68 comprises a networked system 88 and includes one or more processors 90, memory and/or storage components 92, one or more input and/or output devices 94, and a bus 96. Instructions may be stored in one or more computer-readable media of memory/storage components 92. Such

instructions may be read by one or more of the processors 90 via the communication bus 96 which may be in the form of a wired or wireless communication bus.

[0038] The one or more processors 90 may be used to execute such instructions and to implement (wholly or in part) one or more attributes of a methodology, e.g. shifting diverter device 60 to a desired flow position. A user may view output from control system 68 and interact with the control system 68 to affect execution of instructions via input/output device(s) 94. Depending on the embodiment, the computer-readable media may comprise a storage component such as a physical memory storage device in the form of a chip, a chip on a package, a memory card, or another suitable storage component.

[0039] Sometimes the control system components, e.g. components 90, 92, 94, 96, may be used in combination with or may be distributed within network system 88. By way of example, the network system 88 may comprise distributed components 98 which may include one or more of the processors 90, memory/storage components 92, and/or input/output devices 94. The various components may communicate over a network 100 which may comprise the Internet, an intranet, a cellular network, a satellite network, and/or other suitable networks.

[0040] Depending on the parameters of a given application and/or environment, the structure of well system 20 may be adjusted. For example, the electric submersible pumping system 24 may be combined with various other components for use in a wellbore or other type of borehole. Similarly, the diverter device 60 may comprise a variety of valves and/or other flow control and mechanisms. The sensor system 70 also may comprise an individual sensor or a plurality of cooperating sensors to monitor flow rate and/or other parameters related to operation of the electric submersible pumping system 24. The data from sensor system 70 may be provided to a variety of control systems which may be used to enable manual and/or autonomous control of the diverter device 60 and/or other components, e.g. submersible motor 26, of the well system 20. The recirculation system 60, 64, 52 also may be combined with an alarm functionality to

provide the option of triggering an alarm signal during, for example, a blockage event. The alarm signal can be provided via selected communication channels and can be used to alert electric submersible pumping system operators of potential issues, thus enabling the taking of appropriate actions before the potential issues become problematic.

[0041] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

- 1 1. A system for use in a borehole, comprising:
2
3 an electric submersible pumping system having an intake and a discharge,
4 the discharge being located to direct a fluid flow into a primary flow passage
5 extending to a surface location;
6 a diverter valve in fluid communication with the discharge, the diverter
7 valve being selectively actuatable to reroute at least a portion of the fluid flow to a
8 desired location; and
9 a sensor system positioned in cooperation with the electric submersible
10 pumping system to detect when the diverter valve should be actuated to reroute at
11 least a portion of the fluid flow due to detection of reduced flow through the
12 primary flow passage.
- 1 2. The system as recited in claim 1, wherein the desired location is a subterranean
2 location at a desired position with respect to the electric submersible pumping
3 system.
- 1 3. The system as recited in claim 1, further comprising a control system coupled
2 with the sensor system.
- 1 4. The system as recited in claim 3, wherein the control system is configured to
2 automatically actuate the diverter valve in response to a signal received from the
3 sensor system indicating the reduced flow.
- 1 5. The system as recited in claim 3, wherein the control system is positioned at a
2 surface location.

- 1 6. The system as recited in claim 1, wherein the diverter valve is actuatable to
2 reroute the entire fluid flow passing through the discharge.
1
- 1 7. The system as recited in claim 1, wherein the electric submersible pumping
2 system is deployed in a wellbore extending into a geological formation containing
3 petroleum.
- 1 8. The system as recited in claim 1, wherein the electric submersible pumping
2 system comprises a submersible, centrifugal pump.
1
- 1 9. The system as recited in claim 1, further comprising a conveyance coupled to the
2 electric submersible pumping system, the conveyance comprising tubing along
3 which the diverter valve is positioned.
1
- 1 10. A system, comprising:
2
3 an electric submersible pumping system deployed in a wellbore to pump a
4 fluid along a primary flow path to a desired location; and
5 a diverter valve system positioned along the primary flow path, the
6 diverter the system being actuatable to divert at least a portion of the fluid flow
7 from the primary flow path upon occurrence of a potentially detrimental reduction
8 in flow rate of the fluid flowing along the primary flow path.
- 1 11. The system as recited in claim 10, further comprising a sensor to detect the
2 potentially detrimental reduction in flow rate.
- 1 12. The system as recited in claim 11, wherein the sensor system is coupled with a
2 control system which processes data signals from the sensor system.
- 1 13. The system as recited in claim 12, wherein the control system is coupled with the
2 diverter valve system, the control system being configured to automatically

3 actuate the diverter valve system to divert at least the portion of the fluid upon
4 detection of the potentially detrimental reduction in flow rate.

1 14. The system as recited in claim 10, wherein the diverter valve system is deployed
2 downhole proximate a discharge of the electric submersible pumping system.

1 15. The system as recited in claim 10, wherein the diverter valve system diverts at
2 least the portion of the fluid to an intake of the electric submersible pumping
3 system to recirculate fluid.

1 16. The system as recited in claim 10, wherein the electric submersible pumping
2 system comprises a submersible, centrifugal pump.

1 17. A method, comprising:

2
3 positioning an electric submersible pumping system in a borehole;
4 operating the electric submersible pumping system to pump a fluid and to
5 create a fluid flow along a primary flow path;
6 monitoring the fluid flow for a decrease in flow rate that would be
7 potentially damaging to the electric submersible pumping system; and
8 upon detecting the decrease in flow rate, diverting at least a portion of the
9 fluid flow away from the primary flow path to help normalize operation of the
10 electric submersible pumping system.

1 18. The method as recited in claim 17, wherein operating the electric submersible
2 pumping system comprises pumping petroleum received in the borehole from a
3 geologic formation.

1 19. The method as recited in claim 17, wherein monitoring comprises monitoring the
2 fluid flow with a sensor positioned downhole in the borehole.

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20. The method as recited in claim 19, wherein diverting comprises automatically diverting upon detecting the decrease in flow rate.

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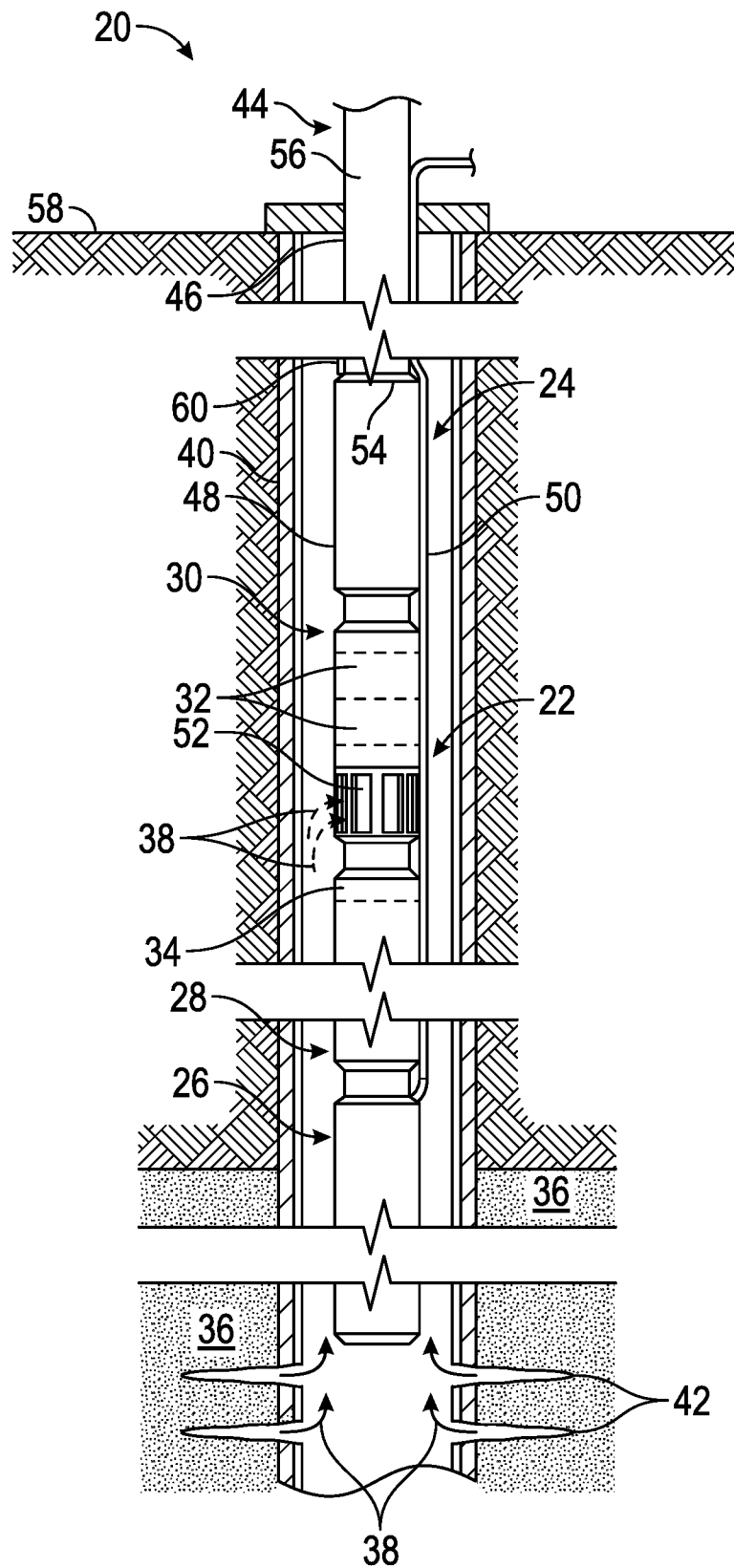


FIG. 1

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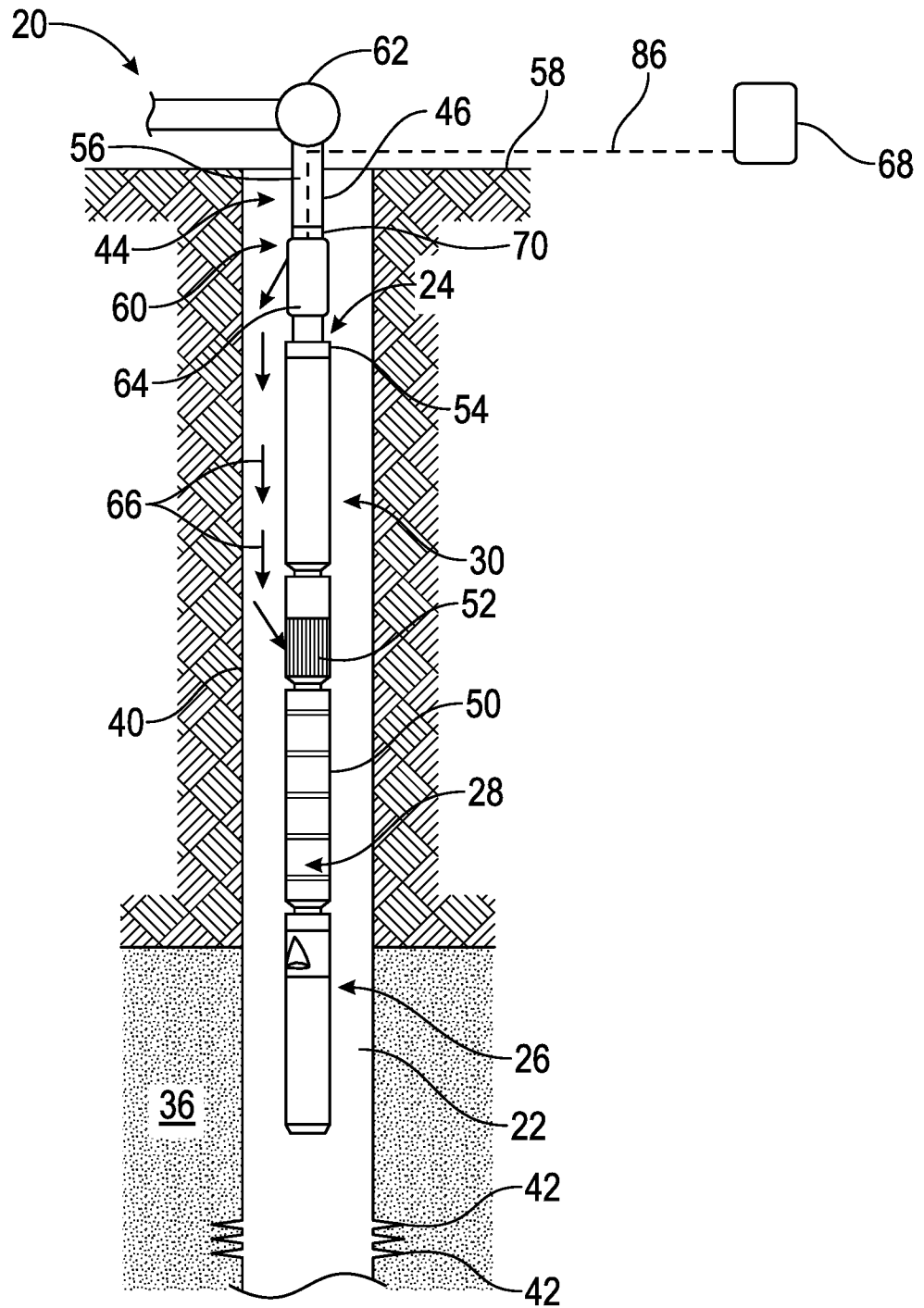


FIG. 2

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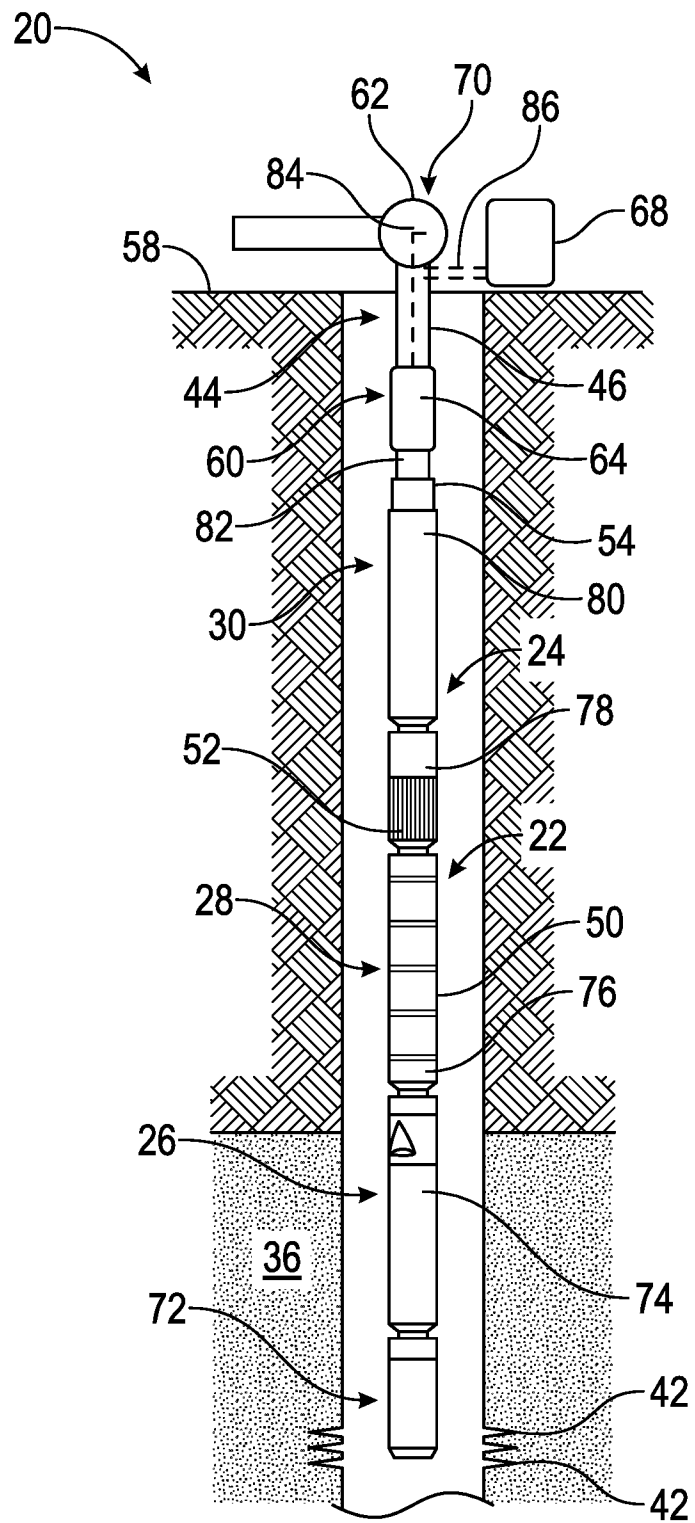


FIG. 3

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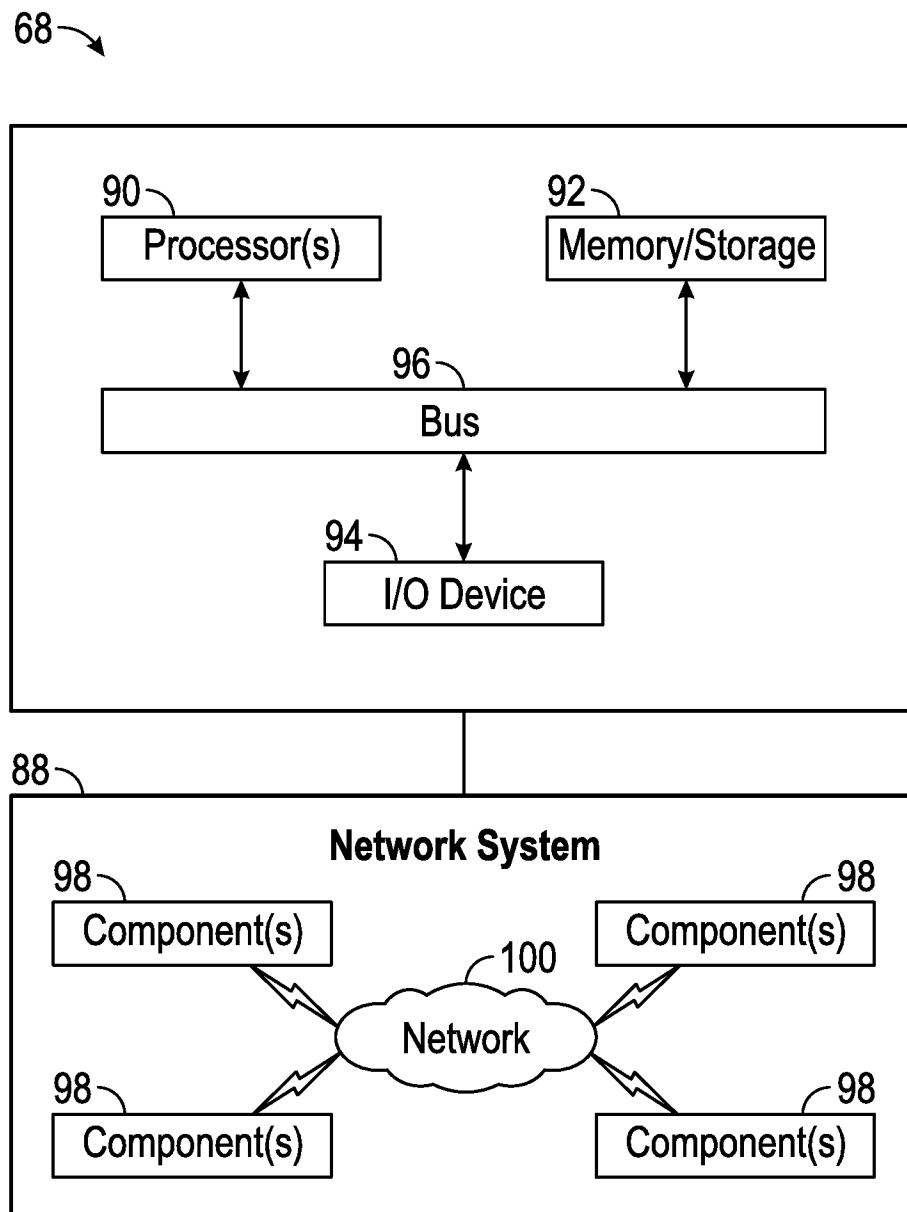


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/021652**A. CLASSIFICATION OF SUBJECT MATTER****F04B 47/06(2006.01)i, E21B 43/12(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F04B 47/06; E21B 43/12; E21B 23/14; G06F 19/00; E21B 43/40; E21B 47/06; G01F 1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: electric submersible pump, bypass, flow rate, sensor, diverter valve, conveyance, and intake

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7530392 B2 (SUGIYAMA et al.) 12 May 2009 See column 4, line 15 - column 5, line 62, claims 2, 13, 17 and figures 3-5.	1-20
A	US 2009-0223662 A1 (SHAW et al.) 10 September 2009 See paragraphs [0018]-[0026] and figure 1.	1-20
A	US 2010-0139388 A1 (GRIFFITHS et al.) 10 June 2010 See paragraphs [0025]-[0032] and figure 1.	1-20
A	US 2009-0288821 A1 (ERIKSEN et al.) 26 November 2009 See paragraphs [0021]-[0028] and figure 1.	1-20
A	US 2010-0228502 A1 (ATHERON, ERIC) 09 September 2010 See paragraphs [0036]-[0040] and figure 3.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

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Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

KIM, Jin Ho

Telephone No. +82-42-481-8699



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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